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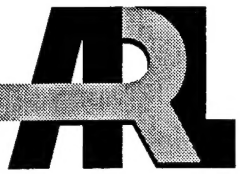

Environmental and Personnel Safety Procedures for High-Power, Radio-Frequency Outdoor Field Tests

by Bruce T. Benwell and Mark D. Berry

ARL-TR-851

June 1996

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This report documents the procedures followed for radio-frequency experiments performed at outdoor, off-site locations. This report identifies potential personnel and environmental hazards, standardizes personnel exposure levels to establish a uniform personnel protection policy, eliminates uncertainties associated with interpreting existing safety and environmental standards, and defines those procedures necessary to assure compliance.

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1. Introduction

Army Regulation (AR) 200-2, *Environmental Effects of Army Actions* [1], states the Department of the Army (DA) policy and establishes the procedures for the integration of environmental considerations in actions that might significantly affect the environment.

One mission of the Army Research Laboratory (ARL) is to perform outdoor, off-site field tests requiring the use of high-power radio-frequency (rf) transmitters. The intent of this report is to (1) identify potential safety and environmental hazards associated with an outdoor (rf) field test, (2) standardize personnel exposure levels to establish a uniform personnel protection policy, (3) eliminate uncertainties associated with interpreting existing safety and environmental standards, and (4) define those procedures necessary to assure compliance with existing regulations to mitigate identified hazards.

Section 2 of this report summarizes the official documentation that is required for any field test; section 3 defines how a generic field test is configured; and section 4 identifies associated personnel and environmental hazards. Section 5 summarizes the pertinent Department of Defense (DoD) and industry standards/limits for each identified potential hazard, and section 6 details the procedures that will be followed for any field test to assure compliance with all identified standards/limits.

2. Official Documentation

When conducting rf outdoor field tests, we must examine possible and probable environmental consequences. It is necessary to first identify the specific source and antenna parameters that will be used (i.e., output power, repetition rate, waveshape, frequency, angle of incidence, antenna gain, etc). This information, together with the proposed test configuration, testplan, and environmental working papers (to be described later), allows us to start contacting site directors and/or facility environmental officials to identify those sites that can accommodate both the test and environmental considerations.

Once a potential site is located, we can begin working with the facility environmental coordinator to identify and address any environmental impacts.

If the proposed action qualifies as a "categorical exclusion," then no further action may be required. Categorical exclusions are those actions that present (1) minimal or no individual or cumulative effect on environmental quality, (2) no environmentally controversial change to existing environmental conditions, and (3) a similarity to actions previously examined and found to meet the above criteria. Appendix A lists the categorical exclusions found in AR 200-2. Many of the categorical exclusions require the submission of a Record of Environmental Consideration (REC). It has been

our policy, though, that even when a categorical exclusion does not require an REC, an REC be prepared to document that we have addressed all environmental considerations.

An REC is simply a formal document that briefly describes the proposed action and its anticipated time frame, identifies the responsible proponent, and explains why further environmental documentation is not required. Appendix B shows the format of a sample REC.

If the proposed action is within the general scope of an existing site Environmental Assessment (EA) or an Environmental Impact Statement (EIS), an REC is also required.

Once a site has been identified, it is necessary to obtain frequency allocation approval to transmit during the proposed test window. This approval is obtained from the Army Frequency Manager assigned to the region where the test site is located.

If the proposed action is not categorically excluded or covered by an existing EA or EIS and the results from the action may affect the environment, a formal EA or EIS will be required. The process of preparing and approving an EA or EIS can be lengthy: up to several years, depending on the scope and impact of the proposed action. It is recommended that either the scope of a proposed action be reduced, or a suitable site (one that already has approval for the proposed action) be selected to preclude the need for an EA or EIS.

3. Test Setup

As shown in figure 1, a typical outdoor rf field test involves the illumination of a device under test (DUT) with rf energy generated by a transmitting rf source placed at a given distance from the DUT. Typically, the rf sources used can operate over a wide range of parameters, including, for example, a frequency range from 0.3 to 15 GHz, pulsewidths from 0.1 to 10 μs, and pulse rates from single shot to 1 kHz. For our field tests, the rf sources are placed inside a 40-ft aluminum trailer, which provides both a stable platform and environmental protection for the sources. The source is attached to an antenna (placed outside of the trailer) through either coaxial cable or waveguide. The antennas are typically commercially available devices with gains ranging from unity to about 33 dBi. The positions of the antennas are mechanically fixed so that they are focused either at a point parallel to the ground or at a point below the horizontal at a target on the ground near the DUT. A fixed position prevents the antenna from being inadvertently positioned in any direction other than from the approved safe area.

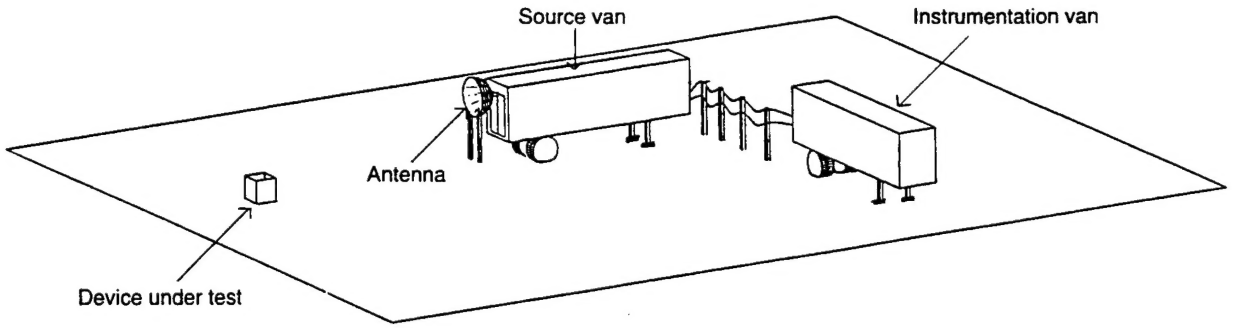

Figure 1. Typical test site layout for an outdoor, off-site field test.

The source is operated from and monitored by equipment located within ARL's System for Monitoring and Recording Transients (SMART) Instrumentation Van (Ivan). The Ivan, a 45-ft electromagnetically shielded instrumentation trailer, houses the entire test team and all of the instrumentation needed to operate the rf source and DUT and to record data signals from both systems.

All connections between the source van and Ivan are wireless (rf, fiber-optic, or pneumatic) to assure that the source cannot be inadvertently triggered by stray signals (created either by ground loops or electromagnetic interference) and to prevent contamination of measured data signals by rf interference.

4. Potential Hazards

The following have been identified as potential environmental and personnel safety hazards associated with outdoor rf field tests.

- *Human exposure (rf).*—Personnel could potentially exceed recommended rf exposure limits if they are too close to the rf source while it is transmitting.
- *Human exposure (x-rays).*—Some high-power rf transmitters produce x-rays due to the normal interaction of the high-voltage, evacuated tubes and filament materials inherent in their construction. X-rays may pose a safety hazard if personnel stand too close to the rf source while it is transmitting.
- *Medical electronics.*—Medical devices (including pacemakers) may experience interference if they are too close to the rf source while it is transmitting.
- *Explosives/fuels.*—The rf source may provide a source of ignition to electro-explosive devices (EEDs) and fuels if they are located too close to the rf source while it is transmitting.
- *Aircraft.*—Electronic equipment associated with low-flying aircraft may experience interference due to the rf source while it is transmitting.

- *Interference with commercial rf electronics.*— While the rf source is transmitting, rf receivers (radio, TV, air traffic control, etc) may experience interference.

- *Hazardous materials.*—The rf source, receiving equipment, or DUT may contain potentially hazardous materials (dielectric insulating oils, batteries, antifreeze, or fuels).

5. Protection Standards/Limits

5.1 Human Exposure (rf)

As a federal agency, ARL is required to conform to permissible exposure levels and procedures as defined in DoD 6055.11, *Protection of DoD Personnel from Exposure to Radio Frequency Radiation* [2], whether testing is performed at ARL or at an off-site location. The rf exposure levels for this standard are based on the *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, ANSI C95.1-1982, or any subsequent revisions (IEEE C95.1-1991) [3].

Continuous exposure.—For uncontrolled environments (areas where personnel have no knowledge or control of their exposure), table 2 of the ANSI standard [3] defines the root mean square (rms) continuous wave (cw) maximum permissible exposure (MPE) limits over our frequency of interest. These limits are summarized in table 1.

The DoD and ANSI standards [2,3] both allow for the relaxation of these limits for controlled environments, partial body exposure, and nonuniform fields, or under special petition. For the sake of policy uniformity, we will adhere to the levels listed in table 1 without exception.

Repetitive/random exposure.—The maximum permissible exposure level (PEL) for pulsed signals, including repetitive, single, and randomly occurring signals are based upon the same PEL for cw exposures (M_{cw}).

Table 1. Permissible continuous wave exposure levels for uncontrolled environments.

Frequency, f (MHz)	Power density * (mW/cm^2)	Averaging time (min)
300–3,000	$f/1{,}500$	30
3,000–15,000	$f/1{,}500$	$90{,}000/f$

* *Under far-field conditions.*

- For repetitive signals (more than five pulses per averaging time) the maximum permissible exposure (M_{rep}) is limited to

$$M_{rep} < \frac{M_{cw}}{D} < 1325.9\ \mathrm{W/cm^2}\ , \tag{1}$$

where D = duty factor (pulsewidth/repetition rate)

- For random or variable pulse repetition rates, the total energy density ($\mathrm{J/cm^2}$) of all pulses summed over the averaging time must be less than M_{cw} × averaging time (s).

- For single pulses, the maximum peak exposure level (M_{pk}) is limited to

$$M_{pk} < \frac{M_{cw} \times \text{averaging time (s)}}{5 \times \text{pulsewidth (s)}} < 1325.9\ \mathrm{W/cm^2}\ . \tag{2}$$

The M_{pk} is only valid if five such pulses occur per averaging time, the pulsewidth is less than 100 ms, and the pulse separation is greater than 100 ms.

If more than 5 such single pulses occur during the averaging time, or if the pulsewidth is greater than 100 ms, normal time-averaging calculations apply with the additional requirement that the total energy density during any 100-ms period is limited to

$$\Sigma M_{pk} \times \text{pulsewidth} = \frac{M_{cw} \times \text{averaging time}}{5}\ . \tag{3}$$

Procedural requirements.—The DoD Standard [2] requires that rf warning signs be placed at all access points to areas where the PEL may be exceeded. The standard also requires that working papers, surveys, calculations, and measurements used to identify potential rf hazards and exclusion zones be maintained and on file.

5.2 Human Exposure (X-Rays)

For uncontrolled areas, the maximum permissible personnel x-ray exposure levels are summarized in table 2. These levels, imposed by the ARL Radiation Control Committee, meet standards set by the Nuclear Regulatory Commission, the Occupational Safety and Health Administration (OSHA), and DA.*

Table 2. Maximum x-ray exposure levels for personnel.

Dose (mrem)	Exposure time
0.2	/hour
10.0	/week
50.0	/year

* *E-mail from M. Borisky, Radiation Protection Officer, ARL Risk Management Branch, to M. Berry, dated 6 March 1995.*

5.3 Medical Electronics (Pacemakers)

Pacemaker manufacturers are not required to meet any specific rf susceptibility level. Historically, manufacturers have followed the susceptibility guidance specified in the Food and Drug Administration (FDA) Pacemaker Standard of August 1975 [4], which recommended that the rf susceptibility level for pacemakers be set at 200 V/m. This recommended susceptibility level was based on the fact that at the time the pacemaker standard was prepared, 10 mW/cm^2 (200 V/m) was the recommended maximum permissible EM environment that a person may encounter under normal circumstances.

Since 1972, the Georgia Tech Research Institute (GTRI) has evaluated commercially available pacemakers to identify their rf susceptibility levels. GTRI has observed that since 1977, manufacturers have met the 200-V/m (10-mW/cm^2) susceptibility level and have concluded that the public can wear these devices "without worry that those conducted and radiated environments most likely to be encountered will pose a threat" [5]. ARL will continue to follow the FDA's original 200-V/m (10-mW/cm^2) PEL. For single pulses or repetitive pulses at rates below 0.1 Hz, a 1000-V/m exposure level is permitted [6].

5.4 Explosives

The keep-out distance for properly stored EEDs (leads twisted and stored within metal packs), for frequencies between 0.4 and 75 GHz, is defined in the *Ammunition and Explosives Safety Standard* [7] as

$$D = (226/f)(PG)^{0.5}, \tag{4}$$

where

D = safe distance between transmitter and EED (ft);
f = frequency (MHz);
P = average power (pulsewidth < 10 μs);
P = peak power (pulsewidth > 10 μs); and
G = linear gain of antenna in direction of EED.

The keep-out distance for a "worst-case" unknown storage configuration (which includes devices unpacked and in use) is defined in table 6-3 of AR 385-64 [7]. This table is reprinted as table 3.

Table 3. Worst-case (exposed devices or of unknown storage) keep-out zone for EEDs.

Effective radiated power (ERP)* (W)	Minimum safe distance (m)
0–30	30
31–50	50
51–100	110
101–250	160
251–500	230
501–1,000	305
1,001–3,000	480
3,001–5,000	610
5,001–20,000	915
20,001–50,000	1,530
50,001–100,000	3,050
100,001–400,000	6,100
400,001–1,600,000	12,200
1,600,001–6,400,000	24,400

**ERP is defined to be the transmitted power × antenna gain.*

Note: When transmission is a pulsed or pulsed continuous wave type and its pulsewidth is less than 10 μs, the power column indicates average power. For all other transmissions, including those with pulsewidths greater than 10 μs, the power column indicates peak power.

5.5 Aircraft

At this time there are no specific Federal Aviation Administration (FAA) regulations addressing high-intensity radiated fields (HIRF) for aircraft, although some new aircraft, as well as aircraft that are modernized with critical control systems, have special HIRF conditions imposed upon them. Current FAA and Joint Aviation Authority (JAA) regulations require that equipment and systems operate as required in their intended environments. However, there are no regulations dealing specifically with the protection of these electrical and electronic systems against the effects of HIRF [8]. To address this deficiency, the FAA/JAA and European Organization for Aviation Equipment (EUROCAE) have formed the Electromagnetic Effects Harmonization Working Group (EEHWG) to define specific requirements to address HIRF. The EEHWG has defined three incident HIRF external environments (severe, certification, and normal) [9] for the purposes of system testing. These levels are based on multinational databases of existing rf transmitters. Table 4 shows the certification HIRF environment, from 400 MHz to 40 GHz. This environment (a subset of the severe HIRF environment) has been established as an estimate of the electromagnetic field strength levels, which could be encountered in routine flight operations.

Table 4. International certification HIRF environment—electromagnetic field strength levels that could be encountered in routine flight operations.

Frequency (GHz)	Field strength (V/m)
0.4–0.7	4020
0.7–1.0	1700
1.0–2.0	5000
2.0–4.0	6680
4.0–6.0	6850
6.0–8.0	3600
8.0–12.0	4240
12.0–18.0	3500
18.0–40.0	2100

Historically, critical aircraft subsystems have been tested to a 200-V/m peak level [10]. Until these HIRF levels are approved, ARL will define a no-fly exclusion zone based on the 200-V/m level. Table 4 does show that the 200-V/m level is an extremely conservative field strength limit for frequencies above 400 MHz.

5.6 Interference with rf Electronics

The Army Frequency Management Office (AFMO) must be consulted before testing to identify potential frequency interference conflicts and to obtain frequency allocation approval.

5.7 Hazardous Materials

All potentially hazardous materials used during testing will be identified and cleared with the facility environmental officer.

6. Assuring Compliance with Standards/Limits

6.1 Engineering Controls

Shielded trailer.—All on-site test personnel are housed within the SMART Ivan trailer, which provides approximately 100 dB of E-field electromagnetic shielding. The rf source can only be controlled from an interlock panel located inside the Ivan.

All connections between the rf source and Ivan are wireless (either rf, fiber-optic, or pneumatic) to assure that the rf source cannot be inadvertently triggered by stray signals created either by ground loops or electromagnetic interference.

A dedicated fiber-optic data channel is also used so that the rf source's transmitting output power can always be monitored to verify that the rf source is operating properly.

As an added safety feature, a dedicated "emergency stop" switch is added to the source's high-voltage power supply to shut down the rf source on demand.

Interlocks.—The rf source is controlled through a keyed interlock system to assure that the rf source will not be operated without completing all safety procedures.

The rf source-operator is assigned a key, which he removes from the interlock panel and carries with him when he leaves the Ivan. The rf source operator is ultimately responsible for visually checking that the safety exclusion zone is clear of personnel, fuels, and EEDs, that all test personnel are accounted for, that no aircraft are within the no-fly zone, and that the site is secure. After operating the rf source, and verifying that the rf source is not transmitting, the operator removes the key from the interlock panel and does not reinstall it until all safety procedures have been completed.

In addition to the source operator key, each person involved with the test is also assigned a key that must be installed in the rf source interlock panel before the rf source can be operated. Anyone leaving the Ivan will remove their key and carry it with him or her. The rf source cannot be operated unless each individual test personnel key and the rf source operator's key have been installed in the interlock panel. This procedure assures that all operating personnel and visitors are in a safe area when the source is transmitting.

Antenna position.—The position of the transmitting antenna will be mechanically fixed to prevent the antenna from being inadvertently positioned in any other direction than from the approved safe area.

X-ray shielding.—When potentially x-ray producing sources are used, adequate lead shielding must be placed around the rf source to absorb these x-rays.

6.2 Procedural Controls

Exclusion zones.—The exclusion zones for aircraft interference, personnel rf and x-ray exposure, and EEDs are unique to each test and are determined by the specific rf source and facility parameters. Appendix C shows the typical calculations involved in the generation of these exclusion zones. For convenience, these separate zones are typically reduced to a single exclusion zone that represents the worst-case (largest) exclusion zone.

Personnel exposure/medical devices

- Exclusion zone: A visual safety exclusion zone, typically constructed of flourescent caution tape, is used to mark the boundary of the PEL to prevent personnel from entering the test area and exceeding the rf PEL.

- Personnel muster: All field test personnel (including visitors) are mustered on a sign-in sheet located within the Ivan. As mentioned above, all members of the test team are assigned a key from the rf source interlock panel that they will keep at all times when leaving the van. The rf source cannot be operated unless all keys are inserted in the interlock panel. The rf source operator will not remove his key from the interlock panel or allow anyone to leave the Ivan until he has monitored the transmitted output power (on a dedicated fiber-optic data channel), to verify that the source is not transmitting.

- Warning signs: rf/microwave warning signs are posted around the test site to warn facility personnel not to enter the test site.

- Visual inspection: Before operating the rf source, the source operator conducts a visual inspection to assure that no one is present in the test area. In addition, a video camera (mounted on the roof of the Ivan) is used to monitor the test area to assure that no one wanders into the exclusion zone.

- Radio communication: All members of the test team, as well as certain facility personnel, are issued a hand radio to allow constant communication. Facility personnel will not enter the test site without gaining approval from the ARL source operator.

Personnel exposure (x-rays).— Test personnel, rf source operators, and visitors (if required) must wear dosimeters provided by the ARL Risk Management Office when x-ray-producing sources are transmitting.

EEDs.—During the test series, it is arranged that all stored EEDs are removed from the keep-out zone. It is the facility's responsibility to alert the ARL test team when EEDs will be in use within the keep-out zones.

Aircraft.—If required, an adequate no-fly zone will be obtained to assure that aircraft will not be exposed to rf fields in excess of 200 V/m. At no time will the rf source be operated when the antenna points above horizontal (to earth ground). As an additional safety measure, the rf source operator will perform a visual inspection to ensure that no aircraft are present before operating the source.

Interference with commercial rf electronics.—Before testing, ARL personnel will receive frequency allocation approval from the AFMO to transmit at the rf source operating frequency.

Hazardous materials.—The following materials are typically used during testing:

- dielectric insulating oil;

- batteries: lead-acid, Ni-Cad, and alkaline;

- SF_6 gas; and

- generator fuels: diesel, gasoline, oil, and antifreeze.

ARL personnel will alert the facility environmental officer as to the type and quantity of all potential hazardous materials before arriving at the site. All materials brought onto the test site by ARL will be removed by ARL upon completion of the test. ARL will provide Material Safety Data Sheets (MSDSs) for the above items if requested. A sample MSDS for the dielectric insulating oil mentioned above can be found in appendix D.

First aid/fire.—First aid kits and fire extinguishers (to be used by the facility fire department only) are stored within the Ivan and rf source trailers. The ARL test team will report any first aid or fire emergencies to facility personnel by radio.

7. Conclusions

While performing off-site outdoor rf field tests, DoD agencies are required to address environmental considerations through compliance with AR 200-2, as well as to assure personnel safety through compliance with DoD 6055.11. Within these regulations are more specific requirements tailored toward the specific proposed actions. These requirements include the generation and filing of documenting working papers, supporting environmental documentation (REC, EA, EIS), supporting approvals (site environmental officer, FAA, AFMO, etc), and safety mitigating procedures.

The regulations, standards, limits, and operating procedures expressed in this document do not encompass all of the potential considerations to be addressed when performing an outdoor rf field test. They do, however, include those that experience has shown to be the most relevant to an outdoor rf field test, and those that are risk conservative and easiest to implement in a timely fashion.

References

1. Army Regulation (AR) 200-2, *Environmental Effects of Army Actions*, 15 March 1985.

2. DoD 6055.11, *Protection of DoD Personnel from Exposure to Radio Frequency Radiation*, dated August 1986.

3. *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, IEEE C95.1-1991, 27 April 1992.

4. *Pacemaker Standard*, Association for Advancement of Medical Instrumentation, FDA Contract No. 223-74-5083, August 1975.

5. *EMC History of Cardiac Pacemakers*, Georgia Technology Research Institute, EMC Test and Design, April 1993.

6. *Final Environmental Impact Statement for the Relocation of the Woodbridge Research Facility Electromagnetic Pulse Simulators*, November 1993.

7. *Ammunition and Explosives Safety Standard*, Army Regulation 385-64, 1993 (Draft).

8. *State of the Art of High Intensity Radiated Fields (HIRF) Technology*, Electro Magnetic Applications, Inc., 24 October 1994.

9. *Second Working Draft for Harmonized FAA Notice of Proposed Rulemaking (NPRM) and JAA Notice of Proposed Amendment (NPA), High Intensity Radiated Fields (HIRF) Standards for Aircraft Electrical and Electronic Systems*, produced by Electromagnetic Effects Harmonization Working Group (EEHWG), 24 May 1994.

10. MIL-STD-461C, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*, 4 August 1986.

Appendix A.—Categorical Exclusions

The following is a list of the categorical exclusions found in Appendix A of Army Regulation (AR) 200-2, *Environmental Effects of Army Actions*, 15 March 1985.

A-1. Normal personnel, fiscal, and administrative activities involving military and civilian personnel (recruiting, processing, paying, and records keeping).

A-2. Law and order activities performed by military police and physical plant protection and security personnel, excluding formulation and/or enforcement of hunting and fishing policies of regulations, which differ substantively from those in effect on surrounding non-Army lands.

A-3. Recreation and welfare activities not involving off-road recreational vehicle management; forestry and fish and wildlife management plans and activities except those that involve introduction of or effect on exotic, endangered, or threatened species.

A-4. Commissary and PX operations.

A-5. Routine repair and maintenance of buildings, roads, airfields, grounds, equipment, and other facilities, except in cases requiring disposal of hazardous or contaminated materials.

A-6. Routine procurement of goods and services, including routine utility services.

A-7. Construction that does not significantly alter land use, provided the operation of the project when completed would not of itself have a significant environmental impact; includes outgrants to private lessees for similar construction. (REC required.)

A-8. Simulated war games and other tactical and logistical exercises without troops.

A-9. Training entirely of an administrative or classroom nature.

A-10. Material storage other than storage of ammunition, explosives, pyrotechnics, and nuclear materials and other hazardous or toxic materials in structures designed and maintained for that explicit purpose.

A-11. Operations conducted by established laboratories in enclosed facilities where

a. all airborne emissions, waterborne effluents, external radiation levels, outdoor noise, and solid or bulk liquid waste disposal practices are in compliance with existing federal, state, and local laws and regulation; and

b. no animal which must be captured from the wild are used as research subjects (excluding reintroduction projects).

A-12. Developmental and operational testing on a military installation, where the tests are conducted in conjunction with normal military training or force maintenance activities so that the tests produce only incremental impacts, if any, and provided that the training and force maintenance activities have been adequately assessed, where required, in other Army environmental documents. (REC required.)

A-13. Routine movement of personnel; routine handling and distribution of nonhazardous materials in conformance with DA, EPA, Department of Transportation, and state regulations.

A-14. Reduction and realignment of civilian and/or military personnel which fall below the thresholds for reportable actions as prescribed in AR 5-10. Conversion of commercial activities (CA) to contract performance of services from in-house performance under the provisions of DoD Directive 4100.15.

A-15. Preparation of regulations, directives, manuals, and other guidance documents related to actions that qualify for categorical exclusion.

A-16. Acquisition, installation, and operation of utility systems and communications data processing, cable systems, and similar electronic equipment which use existing rights of way, easements, distribution systems, and facilities.

A-17. Activities which identify the state of the existing environment without altering it (e.g., inspections, surveys, and investigations), including the granting of any permits necessary for such surveys.

A-18. Deployment of military units on a temporary duty (TDY) basis where existing facilities are used and the activities to be performed have no significant impact on the environment. (REC required.)

A-19. Preparation of regulations, procedures, manuals, and other guidance documents that implement without substantial change the regulations, procedures, manuals, and other guidance documents of higher headquarters or another federal agency which have already been environmentally evaluated.

A-20. Grants of easements for the use of existing rights-of-way for use by vehicles; electrical power, telephone, and other transmission and communication lines; transmitter and relay facilities; water, wastewater, storm water, and irrigation pipelines pumping stations and facilities; and for other similar public utility and transportation uses. (REC required.)

A-21. Grants of leases, licenses, and permits to utilize existing Army controlled property for agriculture and grazing; classroom, office warehouse, and administrative space; housing; other uses similar to previous or current Army use of the property; historical or archaeological studies or preservation; use of non-Army property for Army activities where the action is consistent with existing land-use plans. (REC required.)

A-22. Grants of consent agreements to use a Government-owned easement in a manner consistent with existing Army use of the easement; disposal of excess areas to the underlying fee owner. (REC required.)

A-23. Grants of licenses for the operation of telephone, gas, water, electricity, community television antenna, and other distribution systems normally considered public utilities. (REC required.)

A-24. Transfer of real property administrative control within the Army to another military department or other federal agency, including the return of public domain lands to the Department of Interior and reporting of property available for outgranting; and grants of leases, licenses, permits, and easements for use of excess or surplus property without significant changes in land use. (REC required.)

A-25. Disposal of uncontaminated buildings and other improvements for removal off-site. (REC required.)

A-26. Studies that involve no commitment of resources other than manpower. (REC required.)

A-27. Study and test activities within the procurement program for Military Adaption of Commercial Items for items manufactured in the U.S. (REC required.)

A-28. Development of table organization and equipment documents, no fixed location or site.

A-29. Grants of leases, licenses, and permits to use DA property for or by another governmental entity when such permission is predicated upon compliance with the NEPA. (REC required.)

Appendix B.—Record of Environmental Consideration

The following is an acceptable Record of Environmental Consideration (REC) format, as outlined in Army Regulation (AR) 200-2, *Environmental Effects of Army Actions*, 15 March 1985.

Record of Environmental Consideration

Project Title:

Brief Description:

Anticipated Date and Duration:

It has been determined that the action (choose one)
a) is adequately covered in an existing EA, EIA, EIS, entitled and dated _____
_____

b) qualifies for categorical exclusion CX _____ , AR 200—appendix A, and no extraordinary circumstances exist as defined in paragraph 4-3, AR 200-2, because _____
_____.

Signed:_____
(Office responsible for proposed action)

Date:_____

Concurrence:_____
(Installation Environmental Officer)

Appendix C.—Working Papers

This appendix details the background information typically generated to document that the proper environmental considerations have been addressed and that the necessary precautions have been defined to assure compliance with all identified regulations.

After the environmental working papers have been completed, it is possible to sit down with potential facility coordinators and environmental officials to determine which facilities are able to support this type of action, as well as to identify any additional environmental documentation that will be necessary.

25 July 1994

Revised, 27 September 1994

WORKING PAPERS: Field Test Personnel, EED, and Aircraft Exclusion Zones

Place: ARL, Adelphi MD

Date: 1–21 October 1994

Prepared by: Bruce T. Benwell
Mark D. Berry

These working papers document the personnel and electro-explosive keep-out ranges in accordance with the requirements defined in the Department of Defense (DoD) regulation [1]:

I. Site location

Range: Adelphi, MD

Transmit direction: 310° from magnetic north

II. Source parameters

Peak power (P_{pk}): 16 kW rms

Pulsewidth: 2 μs

Pulse repetition frequency: 400 Hz maximum

Duty factor (D): 800×10^{-6} (pulsewidth × pulse repetition frequency)

Frequency (f): 1250–1350

Antenna gain (G): 33 dBi (× 2000) main beam

(G_{sl}) 18 dBi (× 63) side lobe

Beam width: ≈6 degrees

III. Personnel exclusion zone (uncontrolled environment)

The maximum permissible exposure (M_{rep}) for repetitive signals is defined to be [2]

$$M_{rep} = \frac{M_{cw}}{D} = 1042 \text{ mW/cm}^2 , \quad \text{(C-1)}$$

where

$$M_{cw} = f/1500 \text{ (mW/cm}^2\text{), and}$$

$$f = 1250 \text{ MHz (worst case).}$$

The exclusion zone (uncontrolled environment) is calculated from the radar range equation:

$$M_{rep}(\text{W/cm}^2) = \frac{P_{pk}G}{4\pi r^2},$$

$$1042 \text{ mW/cm}^2 = \frac{16{,}000 \times 2{,}000}{4\pi r^2}, \tag{C-2}$$

$$r/100 = 15.6 \text{ m (main beam)}.$$

If we approximate the magnitude of the side lobes to be down by approximately 15 dB (or 18 dBi gain) and resolve equation (C-2), then

$$1042 \text{ mW/cm}^2 = \frac{16{,}000 \times 63.1}{4\pi r^2}, \tag{C-3}$$

$$r/100 = 3 \text{ m (outside main beam)}.$$

IV. Explosives—minimum safe distance from transmitter

1. For properly stored EEDs (stored within metal packs with twisted leads)* within the main beam, the minimum safe distance from the transmitter is calculated to be [3]

$$\begin{aligned} D &= (226/F)(PG)^{0.5} \\ &= (226/1250)(16{,}000 \times 800 \times 10^{-6} \times 2{,}000)^{0.5} \\ &= 29 \text{ ft} \\ &\approx 9 \text{ m (main beam)}, \end{aligned} \tag{C-4}$$

where D = minimum distance between source and EED (ft);

F = 1250 MHz (worst case); and

P = average power (pulsewidth < 10 μs).

Outside the main beam (G = 63),

$$\begin{aligned} D &= 5 \text{ ft} \\ &\approx 1.6 \text{ m (main beam)}. \end{aligned} \tag{C-5}$$

* *EEDs at this facility are stored within metal packs with leads twisted; conversation with facility explosives coordinator, 17 July 1994.*

2. For EEDs that are not properly stored (or that may be in use), the minimum safe distance from the transmitter is determined, from table 6-3 in Army Regulation (AR) 385-64 [3] for an equivalent radiated power (P_{avg} * G) of 25.6 kW, to be 1530 m within the main beam. This range is based on a clear line of sight from the transmitter to the EED. If foliage attenuation is included [4,5],* the range within the main beam is reduced to 30 m. P_{avg} is used since the pulsewidth of the source is less than 10 μs.

V. Aircraft

The maximum permissible peak exposure for aircraft is 200 V/m [6]:

$$S_{rms}\,(\mathrm{W/m^2}) = E_{pk}^2/(2\times 377) = 53\ \mathrm{W/m^2}. \tag{C-6}$$

The keep-out range is therefore

$$53 = \frac{P_{pk}G_{sl}}{4\pi r^2}$$
$$r = 1.5\ \mathrm{km} = 4884\ \mathrm{ft} < 5000\ \mathrm{ft} \tag{C-7}$$

The facility used for this test maintains a 5000-ft no-fly zone.

VI. Conclusion

The personnel exclusion zone in section III will be designated the "worst-case" exclusion zone since all other exclusion zones fall within this range. This exclusion zone will be visually indicated by the placement of flourescent caution tape at the boundary of the zone.

References

1. *Protection of DoD Personnel from Exposure to Radio Frequency Radiation*, Department of Defense (DoD) Regulation 6055.11, 20 August 1986.

2. *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, Institute for Electrical and Electronics Engineers (IEEE) C95.1-1991, 27 April 1992.

3. *Ammunition and Explosives Safety Standard*, Army Regulation (AR) 385-64, 1993 (DRAFT).

4. *FDR Calculation Between ***** and ARSR 4*, prepared for ARL by U.S. Army CECOM, Space and Terrestrial Communications Directorate, August 1994.

5. *FDR Package of the ECAC-TTP Manual*, section 7.3.7, and supporting data in *ECAC-TN-86-003*, section 2.

6. MIL-STD-461C, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*, 4 August 1986.

Meeting between B. Benwell, M. Berry, and P. Major (CECOM); attenuation for foliage is 0.32 dB/m at 1.25 GHz.

Appendix D.—Material Safety Data Sheet

The following is an example of a Material Safety Data Sheet (MSDS) for the dielectric insulating oil used with several of the high-power transmitting sources.

EXXON COMPANY, U.S.A.
A DIVISION OF EXXON CORPORATION

DATE ISSUED: 09/15/93
SUPERSEDES DATE: 02/10/93

MATERIAL SAFETY DATA SHEET

EXXON COMPANY, U.S.A. P.O. BOX 2180 HOUSTON, TX 77252-2180

A. IDENTIFICATION AND EMERGENCY INFORMATION

PRODUCT NAME
UNIVOLT N 61

PRODUCT CODE
331831 - 01831

PRODUCT CATEGORY
Petroleum Electrical Insulating Oil

PRODUCT APPEARANCE AND ODOR
Clear water-white liquid
Mild, bland petroleum odor

MEDICAL EMERGENCY TELEPHONE NUMBER
(713) 656-3424

B. COMPONENTS AND HAZARD INFORMATION

COMPONENTS	CAS NO. OF COMPONENTS	APPROXIMATE CONCENTRATION
Distillates (petroleum), hydrotreated light naphthenic	64742-53-6	Greater than 99.7%
Proprietary additives	Mixture	Less than 0.3%

This product, as manufactured by Exxon, does not contain polychlorinated biphenyls (PCB's) as per ASTM D 4059.
All components of this product are listed on the U.S. TSCA inventory.
See Section E for Health and Hazard Information.
See Section H for additional Environmental Information.

HAZARDOUS MATERIALS IDENTIFICATION SYSTEM (HMIS)

Health	Flammability	Reactivity	BASIS
1	1	0	Recommended by Exxon

EXPOSURE LIMIT FOR TOTAL PRODUCT	BASIS
5 mg/m3 for oil mist (aerosol) for an 8-hour workday	OSHA Regulation 29 CFR 1910.1000 and recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). ACGIH states that the air is to be sampled by a method that does not collect vapor; in addition, it lists a 10 mg/m3 STEL.

C. PRIMARY ROUTES OF ENTRY AND EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT
If splashed into the eyes, flush with clear water for 15 minutes or until irritation subsides. If irritation persists, call a physician.

SKIN
In case of skin contact, remove any contaminated clothing and wash skin with soap and water. Launder or dry-clean clothing before reuse. If product is

injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a physician as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of injury.

INHALATION
Vapor pressure is very low. Vapor inhalation under ambient conditions is normally not a problem. If overcome by vapor from hot product, immediately remove from exposure and call a physician. If breathing is irregular or has stopped, start resuscitation; administer oxygen, if available. If overexposed to oil mist, remove from further exposure until excessive oil mist condition subsides.

INGESTION
If ingested, DO NOT induce vomiting; call a physician immediately.

D. FIRE AND EXPLOSION HAZARD INFORMATION

FLASH POINT (MINIMUM)
145~C (293~F)
ASTM D 92, Cleveland Open Cup

AUTOIGNITION TEMPERATURE
Greater than 204~C (400~F)
ASTM E 659

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) - HAZARD IDENTIFICATION

Health	Flammability	Reactivity	BASIS
1	1	0	Recommended by Exxon

HANDLING PRECAUTIONS
Use product with caution around heat, sparks, pilot lights, static electricity, and open flame.

FLAMMABLE OR EXPLOSIVE LIMITS (APPROXIMATE PERCENT BY VOLUME IN AIR)
Estimated values: Lower Flammable Limit 0.9% Upper Flammable Limit 7%

EXTINGUISHING MEDIA AND FIRE FIGHTING PROCEDURES
Foam, water spray (fog), dry chemical, carbon dioxide and vaporizing liquid type extinguishing agents may all be suitable for extinguishing fires involving this type of product, depending on size or potential size of fire and circumstances related to the situation. Plan fire protection and response strategy through consultation with local fire protection authorities or appropriate specialists.
The following procedures for this type of product are based on the recommendations in the National Fire Protection Association's "Fire Protection Guide on Hazardous Materials", Tenth Edition (1991):
Use water spray, dry chemical, foam or carbon dioxide to extinguish the fire. Use water to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to provide protection for

men attempting to stop a leak. Water spray may be used to flush spills away from exposures. Minimize breathing of gases, vapor, fumes or decomposition products. Use supplied-air breathing equipment for enclosed or confined spaces or as otherwise needed.

DECOMPOSITION PRODUCTS UNDER FIRE CONDITIONS
Fumes, smoke, carbon monoxide, sulfur oxides, aldehydes and other decomposition products, in the case of incomplete combustion.

"EMPTY" CONTAINER WARNING
"Empty" containers retain residue (liquid and/or vapor) and can be dangerous. DO NOT PRESSURIZE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION; THEY MAY EXPLODE AND CAUSE INJURY OR DEATH. Do not attempt to clean since residue is difficult to remove. "Empty" drums should be completely drained, properly bunged and promptly returned to a drum reconditioner. All other containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations. For work on tanks refer to Occupational Safety and Health Administration regulations, ANSI Z49.1, and other governmental and industrial references pertaining to cleaning, repairing, welding, or other contemplated operations.

E. HEALTH AND HAZARD INFORMATION

VARIABILITY AMONG INDIVIDUALS
Health studies have shown that many petroleum hydrocarbons and synthetic lubricants pose potential human health risks which may vary from person to person. As a precaution, exposure to liquids, vapors, mists or fumes should be minimized.

EFFECTS OF OVEREXPOSURE (Signs and symptoms of exposure)
Prolonged or repeated skin contact may cause skin irritation.

NATURE OF HAZARD AND TOXICITY INFORMATION
In accordance with the current OSHA Hazard Communication Standard criteria, this product does not require a cancer hazard warning. This is because the product is formulated from base stocks which are severely hydrotreated, severely solvent extracted, and/or processed by mild hydrotreatment and extraction. Alternatively, it may consist of components not otherwise affected by IARC criteria, such as atmospheric distillates or synthetically derived materials, and as such is not characterized by current IARC classification criteria.
Prolonged or repeated skin contact with this product tends to remove skin oils, possibly leading to irritation and dermatitis; however, based on human experience and available toxicological data, this product is judged to be neither a "corrosive" nor an "irritant" by OSHA criteria.
Product contacting the eyes may cause eye irritation.
Product has a low order of acute oral and dermal toxicity, but minute amounts aspirated into the lungs during ingestion or vomiting may cause mild to severe pulmonary injury and possibly death.
This product is judged to have an acute oral LD50 (rat) greater than 5 g/kg of body weight, and an acute dermal LD50 (rabbit) greater than 3.16 g/kg of body weight.

PRE-EXISTING MEDICAL CONDITIONS WHICH MAY BE AGGRAVATED BY EXPOSURE
None recognized

F. PHYSICAL DATA

The following data are approximate or typical values and should not be used for precise design purposes.

BOILING RANGE
IBP Approximately 238~C (460~F)
by ASTM D 2887

SPECIFIC GRAVITY (15.6~C/15.6~C)
0.88

MOLECULAR WEIGHT
Approximately 255

pH
Essentially neutral

POUR, CONGEALING OR MELTING POINT
-45~C (-50~F)
Pour Point by ASTM D 97

VISCOSITY
55 SSU @ 100~F

VAPOR PRESSURE
Less than 0.01 mm Hg @ 20~C

VAPOR DENSITY (AIR = 1)
Greater than 5

PERCENT VOLATILE BY VOLUME
Negligible from open container in 4 hours @ 38~C (100~F)

EVAPORATION RATE @ 1 ATM. AND 25~C (77~F) (n-BUTYL ACETATE = 1)
Less than 0.01

SOLUBILITY IN WATER @ 1 ATM. AND 25~C (77~F)
Negligible; less than 0.1%

G. REACTIVITY

This product is stable and will not react violently with water. Hazardous polymerization will not occur. Avoid contact with strong oxidants such as liquid chlorine, concentrated oxygen, sodium hypochlorite, calcium hypochlorite, etc., as this presents a serious explosion hazard.

H. ENVIRONMENTAL INFORMATION

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Recover free product. Add sand, earth, or other suitable absorbent to spill area. Minimize skin contact. Keep product out of sewers and watercourses by diking or impounding. Advise authorities if product has entered or may enter sewers, watercourses, or extensive land areas.
Assure conformity with applicable governmental regulations.

THE FOLLOWING INFORMATION MAY BE USEFUL IN COMPLYING WITH VARIOUS STATE AND FEDERAL LAWS AND REGULATIONS UNDER VARIOUS ENVIRONMENTAL STATUTES:

REPORTABLE QUANTITY (RQ), EPA REGULATION 40 CFR 302 (CERCLA Section 102)
No RQ for product or any constituent greater than 1% or 0.1% (carcinogen).
THRESHOLD PLANNING QUANTITY (TPQ), EPA REGULATION 40 CFR 355 (SARA Sections 301-304)
No TPQ for product or any constituent greater than 1% or 0.1% (carcinogen).
TOXIC CHEMICAL RELEASE REPORTING, EPA REGULATION 40 CFR 372 (SARA Section 313)
No toxic chemical is present greater than 1% or 0.1% (carcinogen).
HAZARDOUS CHEMICAL REPORTING, EPA REGULATION 40 CFR 370 (SARA Sections 311-312)

EPA HAZARD CLASSIFICATION CODE:	Acute Hazard	Chronic Hazard	Fire Hazard	Pressure Hazard	Reactive Hazard	Not Applicable XXX

I. PROTECTION AND PRECAUTIONS

VENTILATION
Use local exhaust to capture vapor, mists or fumes, if necessary. Provide ventilation sufficient to prevent exceeding recommended exposure limit or buildup of explosive concentrations of vapor in air. No smoking, or use of flame or other ignition sources.

RESPIRATORY PROTECTION
Use supplied-air respiratory protection in confined or enclosed spaces, if needed.

PROTECTIVE GLOVES
Use chemical-resistant gloves, if needed, to avoid prolonged or repeated skin contact.

EYE PROTECTION
Use splash goggles or face shield when eye contact may occur.

OTHER PROTECTIVE EQUIPMENT
Use chemical-resistant apron or other impervious clothing, if needed, to avoid contaminating regular clothing, which could result in prolonged or repeated skin contact.

WORK PRACTICES / ENGINEERING CONTROLS
Keep containers closed when not in use. Do not store near heat, sparks, flame or strong oxidants.
In order to prevent fire or explosion hazards, use appropriate equipment. Information on electrical equipment appropriate for use with this product may be found in the latest edition of the National Electrical Code (NFPA-70).

This document is available from the National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.

PERSONAL HYGIENE
Minimize breathing vapor, mist or fumes. Avoid prolonged or repeated contact with skin. Remove contaminated clothing; launder or dry-clean before re-use. Remove contaminated shoes and thoroughly clean before re-use; discard if oil-soaked. Cleanse skin thoroughly after contact, before breaks and meals, and at end of work period. Product is readily removed from skin by waterless hand cleaners followed by washing thoroughly with soap and water.

J. TRANSPORTATION AND OSHA RELATED LABEL INFORMATION

TRANSPORTATION INCIDENT INFORMATION
For further information relative to spills resulting from transportation incidents, refer to latest Department of Transportation Emergency Response Guidebook for Hazardous Materials Incidents.

U.S. DOT HAZARDOUS MATERIALS SHIPPING DESCRIPTION
Not regulated

OSHA REQUIRED LABEL INFORMATION

In compliance with hazard and right-to-know requirements, where applicable OSHA Hazard Warnings may be found on the label, bill of lading or invoice accompanying this shipment.
Note: Product label may contain non-OSHA related information also.

The information and recommendations contained herein are, to the best of Exxon's knowledge and belief, accurate and reliable as of the date issued. Exxon does not warrant or guarantee their accuracy or reliability, and Exxon shall not be liable for any loss or damage arising out of the use thereof.

The information and recommendations are offered for the user's consideration and examination, and it is the user's responsibility to satisfy itself that they are suitable and complete for its particular use. If buyer repackages this product, legal counsel should be consulted to insure proper health, safety and other necessary information is included on the container.

The Environmental Information included under Section H hereof as well as the Hazardous Materials Identification System (HMIS) and National Fire Protection Association (NFPA) ratings have been included by Exxon Company, U.S.A. in order to provide additional health and hazard classification information. The ratings recommended are based upon the criteria supplied by the developers of these rating systems, together with Exxon's interpretation of the available data.

FOR LUBRICANTS TECHNICAL ASSISTANCE CALL: 1-800-443-9966

FOR FUELS TECHNICAL ASSISTANCE CALL: 713-656-5827

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